CULTIVAR

Registration of 'CP 04-1935' Sugarcane

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ABSTRACT

'CP 04-1935' (Reg. No. CV-154, PI 667660) sugarcane (a complex hybrid of *Saccharum* spp.) was developed through cooperative research conducted by the USDA-ARS, the University of Florida, and the Florida Sugar Cane League and was released to growers in Florida on 20 Sept. 2011. CP 04-1935 was selected from the cross CP 94-2059/CP 84-1322 made at Canal Point, FL on 8 Dec. 1998. In the final stage of selection, CP 04-1935 was tested for yield performance at two sand-soil locations along with 15 other genotypes across three crop years and for freeze tolerance in northern Florida for two crop years. CP 04-1935 produced an 11% higher cane yield, a 3.5% higher sucrose content, and a 14.5% higher sucrose yield than the reference sand cultivar CP 78-1628. CP 04-1935 is resistant to brown rust (caused by *Puccinia melanocephala* H. & P. Sydow), orange rust (caused by *Puccinia kuehnii* E.J. Butler), mosaic (caused by *Sugarcane mosaic virus* strain E), to smut (caused by *Ustilago scitaminea* H. & P. Sydow), and to eyespot [caused by the *Bipolaris sacchari* (E.J. Butler) Shoemaker]; it is moderately resistant to leaf scald (caused by *Xanthomonas albilineans* Ashby, Dowson), and to ratoon stunt (caused by *Leifsonia xyli* subsp. *xyli* Evtushenko et al.), but it is susceptible to *Sugarcane yellow leaf virus*. CP 04-1935 performed significantly worse under freeze conditions than CP 89-2143, the Florida industry standard for acceptable freeze tolerance. With its profitability predicted to be 19% higher than that of CP 78-1628, combined with a good disease profile, CP 04-1935 was recommended for planting on sand soils in Florida.

'CP 04-1935' (Reg. No. CV-154, PI 667660) is a sugarcane (a complex hybrid of *Saccharum* spp.) derivative of a long-term recurrent selection program conducted through cooperative research by the USDA-ARS, the University of Florida, and the Florida Sugar Cane League, Inc. The breeding program at Canal Point (CP) was first established in 1919 to produce true seed for the Louisiana sugar industry, which at the time was threatened by a plethora of diseases, mosaic particularly (Stokes and Tysdale, 1962; Bischoff et al., 2009; Gravois et al., 2010). With the success of the program in combating the disease situation in Louisiana, the mission was extended to develop sugarcane cultivars for Florida. As with all sugarcane breeding programs, the CP program capitalized on the worldwide distribution of the very first cultivars (POJs from the Proefstation Oost Java in Indonesia and Co's from Coimbatore, India) and on the philosophy behind the creation of these cultivars to breed and adapt sugarcane to the high-organic soils in Florida: intercrossing among four *Saccharum* species (*S. officinarum, S. barberi, S. sinense,* and *S. spontaneum*) and backcrossing to the *S. officinarum* background to recover the high sucrose genes (Roach, 1972; Tai and Miller, 1978; Sreenivasan et al., 1987). In this context, modern sugarcane cultivars, such as CP 04-1935, are allopolyploids (including aneuploids) with a large genome (100–130 chromosomes). CP 04-1935 is the product of about 12 meioses since the original interspecific crosses (Miller and Tai, 1992).

Early in the program, on the mainland USA, the realization of a narrow genetic background, founded only on 17 clones (Deren, 1995), prompted the breeders at Canal Point to expand the genomic makeup of the CP cultivars (Tai and Miller, 1978; Miller and Tai, 1992; Edmé et al., 2005). That strategy allowed the CP program to be successful at developing and adapting cultivars to the subtropical conditions and to the high-organic soils of the Florida Everglades Agricultural Area (Miller and Tai, 1992; Edmé et al., 2005). To date, about 70 cultivars have been released to the Florida industry, where sugarcane is planted on about 161,000 ha distributed on two major soil

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Abbreviations: CP, Canal Point; CRS, commercial recoverable sucrose; SCYLV, *Sugarcane yellow leaf virus*.

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types: organic, as muck, and mineral, as sand (Rice et al., 2011). Although there is variation in fertility within each soil type, the area planted to sugarcane represents one agroclimatic zone, which has a unimodal rainy season (from June through September) and sporadic freezes that occur during the harvest season (December to February). Consequently, the breeding program targets cultivars for broad adaptation and for stability across the two soil types through high yields of cane and sugar and with resistance and/or tolerance to biotic and abiotic stresses.

The sand-soil environment, compared with muck, presents its own challenges and management system, and as a result, breeding for and identifying sugarcane varieties with genes for maximum yield potential on sand soils is a high priority for the CP program. This specific adaptation was recently acknowledged by Edmé et al. (2005) in terms of larger gains being realized on the organic than on the sand soils, because the program tests the bulk of new genotypes (starting with ~70,000 seedlings) on muck and on-station, and only 135 are advanced to stage 3 (see Materials and Methods) on sand and across farms in each selection cycle. Stages 3 and 4 are the last two phases of field testing in the CP breeding program, which applies an approximately 10% selection pressure at each stage (seedlings, stages 1–4), resulting in a cumulative selection intensity of 0.2 to 0.3% (stage 3) and 0.02 to 0.03% (stage 4). The latest refinement of the selection protocol allows for better matching of cultivars to the sand-soil environment (Glaz and Kang, 2008; del Blanco et al., 2010). With the new strategy in place, CP 04-1935 was tested only on sand soils in stage 4 due to its poor performance observed on muck in the previous stage. It was released based on its high expected profitability derived from high cane and sucrose yields and commercially recoverable sucrose and from its moderate to high resistance to the most important and prevailing diseases in Florida, such as brown rust (caused by *Puccinia melanocephala* H. & P. Sydow), orange rust (caused by *Puccinia kuehnii* E.J. Butler), leaf scald (caused by *Xanthomonas albilineans* Ashby, Dowson), mosaic (caused by the *Sugarcane mosaic virus* strain E), ratoon stunt (caused by *Leifsonia xyli* subsp. *xyli* Evtushenko et al.), eyespot [caused by the fungus *Bipolaris sacchari* (E.J. Butler) Shoemaker], and smut (caused by *Ustilago scitaminea* H. & P. Sydow). However, CP 04-1935 is susceptible to the *Sugarcane yellow leaf virus* (SCYLV), which is considered to be a relatively minor disease in Florida.

Methods

On-Station Yield Trials

The cross (X98-433) between CP 94-2059 and CP 84-1322 was made at Canal Point on 8 Dec. 1998, with CP 84-1322 being the male (pollen) parent (Table 1). Both parents, as stage-4 advanced breeding lines from their respective CP series, were entered into the parental pool, although they were not released as cultivars. True seeds of this and other crosses were planted in flats in January 2003 and kept in a heated greenhouse until the seedlings were properly hardened to be transplanted to the field in May 2003 on station at Canal Point. The seedling stage comprised approximately 50,000 genotypes, which were visually inspected to eliminate undesirable seedlings based on low vigor, disease incidence, lodging, and any other defect. A previous planting of the seedlings of the X98-433 cross in June 2002 did not result in any selection that became a cultivar; however, the phenotypic appeal (visual selection for vigor, stalk population and size, and disease) of this cross justified another planting in 2003 from which CP 04-1935 was derived.

Four selection steps (stages 1 to 4) followed the seedling stage in the CP breeding program. About 10,000 genotypes were selected from the 2003 seedling stage by cutting one stalk from each stool and advancing it to stage 1 in January 2004. With each clonal propagation, the genotype of the individual is fixed and identical to the mother plant. Stage-1 clones were planted in one-row plots 0.5 m long spaced 1.5 m apart and were separated by 0.5-m alleys. By visual selection against disease incidence, recumbence, and low vigor, 1440 individuals were advanced to a stage-2 test, which was planted on 9 Dec. 2004 on-station at Canal Point. CP 04-1935 was then assigned its name according to routine Canal Point protocol, being the 935th of the other clones tested in 2005 in the first clonal selection stage.

The stage-2 test layout was arranged as an augmented design in eight sections, each of which was 13 plots wide by 16 blocks long; each plot comprised two rows that were each 4.5 m long and spaced 1.5 m apart. The experimental clones were unreplicated and tested against five reference cultivars—'CP 65-357' (Breaux et al., 1974; CANE 9904), 'CP 70-1133' (Rice et al., 1978; MIA 34310), 'CP 72-2086' (Miller et al., 1984; CSR 458), 'CP 78-1628' (Tai et al., 1991; MIA 34310), and 'CP 89-2143' (Glaz et al., 2000; PI 607918)—which were interspersed at least 10 times each across the field. Filler plots were added as border rows. Blocks were separated alternately by alleys that were 1.5 m wide and

Table 1. Summary of the decision process leading to the release of sugarcane cultivar CP 04-1935 in Florida.

Year	Month	Stage and selection decision	Genotypes in stage	Locations
1998	December	Cross made at USDA-ARS Sugarcane Field Station	—	On station
2003	May	Germinated true seed transplanted into field (seedlings)	50,000	On station
2004	January	Advanced from plant-cane seedlings to stage 1	8000	On station
2004	September	Assigned name CP 04-1935 in stage 1	8000	On station
2004	December	Advanced from plant-cane stage 1 to stage 2	1500	On station
2005	November–December	Advanced from plant-cane stage 2 to stage 3	135	Four growers' farms
2007	November–December	Advanced from first-ratoon stage 3 to stage 4 sand soils	13	Two growers' farms
2011	September	Cultivar release	1	—

6 m long. A scouting of the field in July 2005 eliminated 580 plots that did not meet minimum standard for disease resistance and growth habit. Stalks were counted on the remaining plots in July and August 2005, and in October 2005, 10-stalk samples were collected from these plots and weighed to calculate the cane yield (*C*):

$$C\ (\text{Mg ha}^{-1}) = \text{stalk weight (kg stalk}^{-1}) \times \text{stalk number (stalks ha}^{-1}) \div 1000$$

The samples were then milled to calculate the theoretical recoverable sucrose content using a 10% fiber content across genotypes. Those values were converted to commercially recoverable sucrose (CRS), as per Legendre (1992), based on a 0.86 correction factor. Sucrose yield (*S*) was calculated as

$$S\ (\text{Mg ha}^{-1}) = C\ (\text{Mg ha}^{-1}) \times \text{CRS (kg Mg}^{-1}) \div 1000$$

A theoretical economic index as profitability was calculated according to a procedure that integrates sucrose content with the costs of harvesting, hauling, and milling the cane in Florida (Deren et al., 1995). The advancement of 135 genotypes to stage 3 was based primarily on *C*, *S*, profitability, and tolerance to the most important diseases prevailing in Florida: brown rust, orange rust, leaf scald, mosaic, ratoon stunt, eyespot, and smut. Field inoculation (explained in "Disease Screening" below) tests were carried out in stage 2 for ratoon stunt and rust.

Off-Station Yield Trials

Four stage-3 yield trials were planted off-station in November-December 2005 on three commercial fields (A. Duda & Sons, Inc.; Okeelanta Corporation; and Sugar Farms Cooperative North–Osceola Region) with organic soils and on one (Hilliard Brothers of Florida, Ltd.) with sand soil. The 135 genotypes, including CP 04-1935, were tested against three reference cultivars—CP 72-2086, CP 78-1628, and CP 89-2143—in randomized complete block designs with two-replicate plots that were each 4.5 m long and spaced 1.5 m apart. Yield and field disease data were collected in the plant-cane (October 2006 and January 2007) and in the first-ratoon (October 2007) crops and yield was expressed as estimates of cane yield, sucrose yield, and economic index. Artificial inoculations for leaf scald and mosaic supplemented the field observations on all diseases (see "Disease Screening" below). These selection criteria were used to select CP 04-1935 along with 12 other genotypes for advancement to stage 4. Since CP 04-1935 had poor yield performance on the muck soils, the decision was made to plant it exclusively on sand soils in stage 4.

The stage-4 tests with CP 04-1935 and three reference cultivars (CP 72-2086, CP 78-1628, and CP 89-2143) were planted on sand soils within commercial fields at two growers' farms (Hilliard Brothers and Lykes Brothers, Inc.) in December 2007. Plots were three rows wide, 10.5 m long, and arranged in randomized complete block designs with six replications of each genotype. A stalk count was taken on two competitive rows of each plot from July through September in 2008 (plant cane), in 2009 (first ratoon), and in 2010 (second ratoon). Ten-stalk samples were collected from the middle row of each plot from October through March in 2007–2008 (plant cane), 2008–2009 (first ratoon), and 2009–2010 (second ratoon), weighed and milled to derive cane yield, CRS, sucrose yield, and economic index. The fiber content of CP 04-1935 was determined as described by Glaz et al. (2009).

Disease Screening

Disease screening of CP 04-1935 was conducted by inoculation testing and/or monitoring for natural infection to smut, leaf scald, brown rust, orange rust, mosaic, SCYLV, eyespot, and ratoon stunt. For rust, tests were carried out in stages 2 through 4 in separate fields: a suspension of 10^4–10^5 spores mL^{-1} was dropped into the whorl of the plants, which were evaluated a month after inoculation. The genotypes were rated on a five-point scale based on the size and number of uredia: 0 (resistant), 1 (moderately resistant), 2 (moderately susceptible), 3 (susceptible), and 4 (highly susceptible). Field inoculation tests with smut were conducted during stages 3 and 4 in separate fields, by planting seedcane (eyepieces) previously dipped in a suspension of 10^5 spores mL^{-1} for 30 min. Susceptibility to smut in inoculated tests was determined by comparing the number of sori produced by CP 04-1935 with those produced by 'CP 73-1547' (Miller et al., 1982; CSR 455) and CP 78-1628. The susceptibilities of CP 73-1547 and CP 78-1628 to smut are at the upper limits of acceptability for commercial production in Florida.

Greenhouse inoculations were conducted with leaf scald and mosaic in 2006 and 2007. Suspensions (10^6 mL^{-1}) of *Xanthomonas albilineans* were made from infected leaves and sprayed on both ends of the seedcane (eyepieces): the eyepieces of the genotypes in stages 3 and 4 were later planted in flats filled with a potting mix. CP 04-1935 was compared with 'CP 80-1743' (Deren et al., 1991; PI 542104) for the number of infected plants with leaf scald and with CP 72-2086 for the number of infected plants with mosaic. Natural infection levels of CP 80-1743 for leaf scald and of CP 72-2086 for mosaic are at the upper limits of acceptability for commercial production in Florida.

Inoculation tests to compare ratoon stunt susceptibility of CP 04-1935, 'CP 72-1210' (Miller et al., 1981; MIA 34313), and 'CP 80-1827' (Glaz et al., 1990; PI 532837) were conducted from 2005 through 2007. Infection was realized by cutting the seedcane of each genotype with a knife previously dipped into juice collected from plants infected with ratoon stunt. The level of susceptibility is determined by counting the number of colonized vascular bundles stained on a tissue blot relative to the two reference cultivars for ratoon stunt.

Freeze Tolerance

Stage-4 genotypes are routinely planted at the Hague Farm of the Institute of Food and Agricultural Sciences, University of Florida, for testing their field performance after exposure to freeze conditions. Twenty-one genotypes, including CP 04-1935 and three reference cultivars (CP 72-2086, CP 78-1628, and CP 89-2143), were subjected for two crop-years to freezing temperatures in a field experiment established on 25 Feb. 2009 as randomized complete block designs with four replications in single-row plots that

were 2.65 m long and spaced 1.5 m apart. On the sandy soil at the Hague farm, CP 89-2143 is usually better or as good as CP 78-1628 and both are better than CP 72-2086 in maintaining their sucrose content for a longer period of time subsequent to freezes (Edmé and Glaz, 2013). In the first-ratoon crop, samples of five mature stalks were cut from each plot on 10 and 17 Dec. 2010 and on 10 and 27 Jan. 2011. Plots were exposed to temperatures between –3.0 and –6.0°C for 20 h before 10 Dec. 2010 and for an additional 20 h before 17 Dec. 2010. Later, plots were exposed to 35 h of temperatures between –3.0 and –7.5°C before 10 Jan. 2011, followed by 18 h of temperatures between –3.0 and –6.5°C before 27 Jan. 2011. In the second-ratoon crop, plots were sampled five times—on 9 and 30 Nov. 2011, on 6 and 25 Jan. 2012, and on 9 Feb. 2012—and the temperature profile corresponding to each sampling date was as follows: above 0°C for the sampling on 9 Nov. 2011; 6 h at –2.2°C for the 30 Nov. 2011 sampling; 4 h at –2.8°C plus 4 h at –7.8°C for the 6 Jan. 2012 sampling; 3 h at –2.8°C for the 25 Jan. 2012 sampling; and 2 h at –1.7°C for the 9 Feb. 2012 sampling. Samples were taken to Canal Point for milling and analysis of sucrose content from extracted juice. The freeze-tolerance assessment was based on the temporal deterioration of the percentage sucrose from that in the field and expressed relative to that of CP 89-2143, which is the standard for freeze tolerance in the Florida sugarcane industry.

Agronomic and Botanical Descriptions

Data for the agronomic and botanical descriptions of CP 04-1935 were recorded on 10 representative stalks sampled on 21 Aug. 2011, after approximately 265 d of growth from the test at Hilliard (located near Clewiston, FL). Stalks were sampled from the inner rows and the agronomic and botanical descriptions were based on those of Artschwager and Brandes (1958). Colors were characterized according to the Munsell Color Charts for Plant Tissues (Munsell Color Co., 1977). Stalks of CP 04-1935 were compared with those of CP 78-1628.

Characterization by Microsatellite Genotyping

CP 04-1935 was fingerprinted with six pairs of microsatellite primers (Table 2) that were developed through the International Consortium for Sugarcane Biotechnology (Cordeiro et al., 2003). The fingerprint developed for CP 04-1935 was compared with those of cultivars CP 72-2086, CP 78-1628, CP 80-1743, CP 88-1762 (Tai et al., 1997), and CP 89-2143. These five major commercial cultivars occupied 81% of the commercial sugarcane in Florida in 2009 (Rice et al., 2010). Conditions for PCR reactions were as previously described (Glynn et al., 2009) with the following modifications: the thermocycling consisted of 95°C for 3 min, 94°C for 45 s, 6 cycles of 68°C for 5 min (decreasing by 2°C per cycle), 72°C for 1 min, 94°C for 45 s, 8 cycles of 58°C for 2 min (decreasing by 1°C per cycle), 72°C for 30 s, and 24 cycles of 94°C for 45 s, 50°C for 2 min and 72°C for 30 s followed by a final extension of 72°C for 7 min. CP 04-1935 was also genotyped for *Bru*1, a major gene for resistance to brown rust (Asnaghi et al., 2004).

Statistical Analyses

Individual analyses were performed for each crop cycle of the stage-4 tests using a mixed model procedure that considered genotypes as fixed effects and locations and replications within locations as random effects. The combined analyses of the three crop-years (plant-cane, first-ratoon, and second-ratoon) were based on a mixed model in which genotypes and crop cycles were treated as fixed effects and locations, replications within locations, and any interaction with locations were included as random effects. All analyses were performed with the MIXED procedure of SAS v.9.2 (SAS Inst., 2003). Differences among genotypes for each trait were declared significant based on Student's paired *t* test procedure at $P \leq 0.05$. For the freeze tolerance evaluation, the data were analyzed according to an additive main effects and multiplicative interaction model and the adjusted values were used to calculate the relative changes in the percentage sucrose (Edmé and Glaz, 2013). Freeze-tolerance rankings were based on temporal deterioration of the percentage sucrose after exposure to freezing temperatures and expressed relative to that of CP 89-2143.

Characteristics

Pedigree

The recurrent breeding and selection philosophy in the sugarcane breeding program at Canal Point exploits the entry of advanced breeding lines in stage 4 into the parental pool. This strategy permits recombining the best with the best and developing new segregants from complementary parents. Both parents of CP 04-1935 (CP 84-1322 and CP 94-2059) were not released for commercial production after their respective stage-4 tests but were maintained in the working germplasm for a long period of time (a 10-yr time interval separates these two generations) to allow their intermating. This had the added advantage of slowing down the decrease in genetic diversity by recycling rare and previously lost alleles. Through both parents, CP 04-1935 has nine previously released cultivars in its pedigree, such

Table 2. Size range and number of fragments generated by each of six microsatellite primer pairs in CP 04-1935 compared with five sugarcane cultivars (CP 72-2086, CP 78-1628, CP 80-1743, CP 88-1762, CP 89-2143).

		Number of fragments		
			From CP 04-1935	
Primer name	Size range of fragments	Total (all six cultivars)	Total	Unique
	bp			
SMC222CG	146–214	3	3	1
SMC221MS	111–155	6	3	1
SMC179SA	115–219	12	7	2
SMC1493CL	105–169	12	8	1
mSSCIR14	205–256	7	6	2
mSSCIR53	163–246	4	4	2

as 'CP 52-68' (Bischoff et al., 2008), 'CP 56-63' (Hebert et al., 1969; CSR 417), CP 62-374; CSR 421), 'CP 63-588' (Rice et al., 1969; CSR 422), CP 65-357, CP 70-1133, CP 72-1210, CP 72-2086, and 'CP 85-1308' (Tai et al., 1995; PI 583848). Moreover, CP 04-1935 is a descendant of the Co lineage side of the CP pedigree (Tai and Miller, 1978), with Co 281 and Co 421 as its great-great-grandparents. It is customary at Canal Point to repeat planting crosses with visually superior performance in the seedling field. It took three plantings of the CP 94-2059/CP 84-1322 cross to ultimately yield a cultivar with superior performance on the sand soils of Florida.

Field Performance

In the stage-3 tests, CP 04-1935 performed significantly worse than the reference cultivars on muck soils but significantly better on sand soils for all selection criteria. In the two stage-4 tests, CP 04-1935 had higher sucrose yields than the reference cultivar for sand soils (CP 78-1628) on average for all yield traits (Table 3): 26% higher population of stalks, 11% higher cane yield (115 vs. 104 Mg ha^{-1}), 3.5% higher CRS (129 vs. 125 kg Mg^{-1}), and 14.5% higher sucrose yield (15 vs. 13 Mg ha^{-1}). Consequently, CP 04-1935, with a \$2,801 ha^{-1} return, is expected to be 19% more profitable than CP 78-1628 (\$2,357 ha^{-1}) on sand soils. Even though CP 04-1935 carried more stalks per hectare than CP 78-1628, both cultivars had similar mean stalk weights.

Table 3. Plant-cane, first-ratoon, and second-ratoon crop stalk weights, cane yields, commercial recoverable sucrose values, sucrose yields, and economic indices of CP 04-1935 and two reference cultivars planted on sand soils at two locations in stage 4 of the Canal Point breeding program.

	Crop cycle			
Cultivar	Plant cane	First ratoon	Second ratoon	Mean
		Stalk weight (kg)		
CP 04-1935	1.2	0.8	0.8	0.9
CP 78-1628	1.5	0.8	0.8	1.0
p > *t*	NS	NS	NS	NS
		Cane yield (Mg ha^{-1})		
CP 04-1935	147.57	94.91	102.84	115.11
CP 78-1628	141.52	78.83	91.53	103.96
p > *t*	NS	< 0.01	0.05	< 0.01
		Commercial recoverable sucrose (kg Mg^{-1})		
CP 04-1935	139.6	128.5	118.9	129.0
CP 78-1628	138.0	122.6	113.7	124.8
p > *t*	NS	< 0.01	< 0.01	0.05
		Sucrose yield (Mg ha^{-1})		
CP 04-1935	20.66	12.13	12.23	15.01
CP 78-1628	19.50	9.52	10.34	13.12
p > *t*	NS	< 0.01	< 0.01	< 0.01
		Economic index (\$ ha^{-1})		
CP 04-1935	4372	2183	1847	2801
CP 78-1628	4048	1573	1450	2357
p > *t*	NS	< 0.01	< 0.01	< 0.01

The fiber content of CP 04-1935 was 105.7 g kg^{-1}, or 10.6%, compared with 10.4% for CP 78-1628.

In the CP program in Florida, decisions to advance and release varieties for commercial production are made by a committee composed of sugarcane farmers and scientists from the public and private sectors. On 1 June 2011, members of this committee recommended CP 04-1935 for commercial production on sand soils only, on the basis of the higher profitability to be derived from its high yields of cane and sucrose and from its moderate to high resistance to all major and minor sugarcane diseases found in Florida.

Agronomic, Botanical, and Molecular Descriptions

CP 04-1935 measured 280 cm in length (taken from the ground to the top visible dewlap) and was of similar height as CP 78-1628 (273 cm) (Table 4). However, the stalks of CP 78-1628 were larger in diameter (24.7 mm) and had longer internodes (19.7 cm) than CP 04-1935 (22.5 mm and 18.1 cm). No growth cracks were noticed on CP 04-1935, whereas a heavy wax layer was deposited on the internodes. The mean width of the root bands on the stalks, measured at the 6th and 10th internodes from the ground, was 6 mm for CP 04-1935 and 7 mm for CP 78-1628. The root band of CP 04-1935 had a green-yellow color (2.5GY 8/4).

No bud furrows were observed on either CP 04-1935 or CP 78-1628. The buds of CP 04-1935 were yellow (5Y 8/6), 6.8 mm long, 7.07 mm wide, and round with a central germ pore, whereas on CP 78-1628, they were a shade of green yellow (2.5 GY 8/4), 8.5 mm long, 7.2 mm wide, and ovate with an emarginated basal wing region (Table 4).

CP 04-1935 tended to have shorter (146 cm) and narrower (3.3 cm) leaves with narrower midribs (3.6 mm) than CP 78-1628 (188 cm, 4.0 cm, and 5.5 mm, respectively). The leaf sheaths adhered tightly to the stalks on both CP 04-1935 and CP 78-1628 and had sparse pubescence in the center. The midribs were white on the adaxial side of the leaf for both cultivars but of a different shade of green/yellow on the abaxial side: 7.5 GY 5/4 for CP 04-1935 and 7.5Y 6/4 for CP 78-1628. Auricles were present on both cultivars but were long and lanceolate (Table 4). CP 04-1935 had yellow (5Y 6/2) crescent ligules with lozenge, whereas CP 78-1628 had yellow (5Y 7/2) crescent ligules with a broad lozenge.

The six microsatellite primer pairs amplified 44 fragments in the six genotypes, ranging from 3 to 12 fragments per primer pair. The sizes of the fragments ranged from 105 bp to 256 bp (Table 2). Of the 31 fragments scored, 23 were polymorphic and 8 were monomorphic. CP 04-1935 shared 19 fragments with CP 72-2086 and with CP 78-1628, 15 with CP 80-1743, 16 with CP 84-1198 (Glaz et al., 1994), and 14 with CP 89-2143. Nine fragments were unique to CP 04-1935, and they were identified in the fingerprints obtained with primer pairs mSSCIR14 (219 and 230 bp), mSSCIR53 (219 and 233 bp), SMC222CG (211 bp), SMC179SA (197 and 208 bp), SMC1493CL (159 bp), and SMCss1MS (134 bp). The *Bru*1 fragment for rust tolerance was not detected in CP 04-1935.

Table 4. Botanical characteristics of sugarcane cultivar CP 04-1935 and reference cultivar CP 78-1628 as measured in field plantings on a sand soil at Hilliard Brothers Farm near Clewiston, FL.

Trait†	CP 04-1935	CP 78-1628
Stalk height (cm)	280	273
Stalk diameter (mm):		
Low	22.9	28.9
Middle	22.5	24.7
Upper	16.7	22.2
Leaf sheath pubescence	Yes	Short and sparse in center
Leaf length (cm)	146	188
Leaf width (cm)	3.3	4.0
Leaf midrib width (mm)	3.6	5.5
Stalk bud shape	Round with central germ pore	Ovate with emarginated basal wing region
Stalk bud length (mm)	6.8	8.5
Stalk bud width (mm)	7.1	7.2
Short auricle shape	Absent	Absent
Long auricle shape	Lanceolate	Lanceolate
Internode shape	Conoidal	Conoidal
Internode length (cm)	18.1	19.7
Growth cracks	None	Light
Bud furrows	None	None
Root band width (mm)	6	7
Growth ring width (mm)	5.3	2.5
Dewlap (leaf collar) shape	Deltoid descending	Deltoid
Ligule shape	Crescent with lozenge	Crescent with lozenge

†Internode length, bud width and length, root band width, and growth-ring width measured at the 6th and 10th internodes from the ground. Stalk diameters measured at the 2nd, 6th, and top internodes. Stalk and leaf traits are means of 10 measurements.

Disease Reactions

Based on field observations, CP 04-1935 was considered to be resistant (no pustules) to brown rust and orange rust (Table 5), which are the two most serious diseases in the Florida sugarcane industry. However, CP 04-1935 does not contain the fragment of the *Bru1* gene, implying that another gene in the CP population may be providing resistance against the pathogen. CP 04-1935 showed no symptoms of eye spot or of mosaic in the field throughout the experimental phase. In inoculation tests for the mosaic virus, very few plants of CP 04-1935 were infected in 2007 (2%), in 2008 (9.1%), and in 2009 (0%) relative to the high infection levels recorded for CP 72-2086 (21%, 66%, and 31%, respectively).

Based on natural infection symptoms observed, CP 04-1935 was classified as susceptible to SCYLV, as are most other CP genotypes and commercial sugarcane cultivars in Florida. A 3.4 to 8.0% loss in sucrose yield has been recorded in Florida as a result of infection by this virus (Flynn et al. (2005). Smut occurring by natural or artificial infection was not detected in the field plots of CP 04-1935, and for this reason, it is considered to be resistant to the fungus when compared with three sori detected in CP 73-1547 and six sori detected in CP 78-1628 (Table 5). CP 04-1935 showed significant levels of infection for leaf scald in the inoculation tests conducted in 2007 (18%), 2008 (33%), and in 2009 (29%). Comparative infection levels in CP 80-1743 were 62%, 38%, and 21%, respectively. Since no natural infection by leaf scald was observed in the field and taking into account that CP 80-1743 is still planted commercially in Florida, CP 04-1935 is considered to be moderately resistant to *Xanthomonas albilineans*.

Ratoon stunt is a disease that can be controlled with the use of uninfected planting material, good cultural practices, or hot-water treatment. When present, ratoon stunt can cause sucrose yield losses of 5% in Florida (Dean and Davis, 1990) via significant reductions in stalk number and cane yield (Comstock, 2008). Based on the field inoculation tests

Table 5. Disease reactions of sugarcane cultivar CP 04-1935 and reference cultivars CP 72-2086, CP 78-1628, and CP 89-2143 in Florida.

Cultivar	Mosaic	Smut	Brown rust	Orange rust	Leaf Scald	Ratoon stunt	*Sugarcane yellow leaf virus*
CP 04-1935	R†	MR	R	R	MR	MR	S
CP 72-2086	S	R	MR	S	R	R	S
CP 78-1628	R	S	S	MS	MS	MS	S
CP 89-2143	MS	R	R	S	MS	MS	S

†R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible.

conducted in 2005, 2006, and 2007, 0, 12, and 2% of the vascular bundles were infected in CP 04-1935 compared with 18, 10, and 13% in CP 72-1210. CP 04-1935 was declared to be moderately resistant to the effects of ratoon stunt.

Freeze Tolerance

In the first-ratoon crop, CP 04-1935 ranked 18th among the 21 genotypes tested at the Hague Farm, and with a 30% average loss in sucrose content across time, it was considered to be less tolerant than CP 89-2143 (ranked 12th with a 22% loss) and CP 78-1628 (ranked 13th with a 25% loss). Under less severe nighttime freezes, which occurred in the second-ratoon crop, CP 04-1935 ranked 18th in the test, corresponding to an average loss of 12% in sucrose content whereas CP 78-1628 and CP 89-2143 ranked 6th, corresponding to a similar average loss of 10%. Under commercial production in Florida, CP 04-1935 will need to be harvested before CP 89-2143 whenever air temperatures drop to around –3°C.

Availability

In its initial year of release, stalk sections for planting (seed cane) of CP 04-1935 will be available from the Florida Sugar Cane League, Inc. for commercial planting in Florida. It is not anticipated that patent protection for CP 04-1935 will be sought. Small quantities of seed cane for research purposes may be obtained at the USDA-ARS Sugarcane Field Station, Canal Point, FL, where CP 04-1935 will be maintained for at least 5 yr from the date of this publication.

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